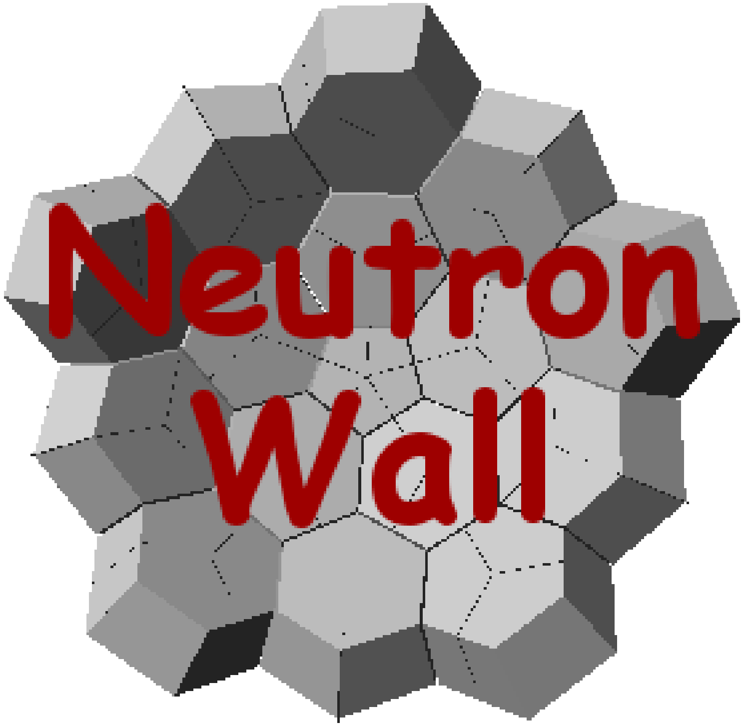
UPPSALA UNIVERSITET

Institutionen
för kärn- och
partikelfysik
(IKP)
Department of
Nuclear and
Particle Physics



http://nsg.tsl.uu.se/nwall/

Johan Nyberg

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- Detectors and mechanics
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- Performance
  - neutron-gamma separation
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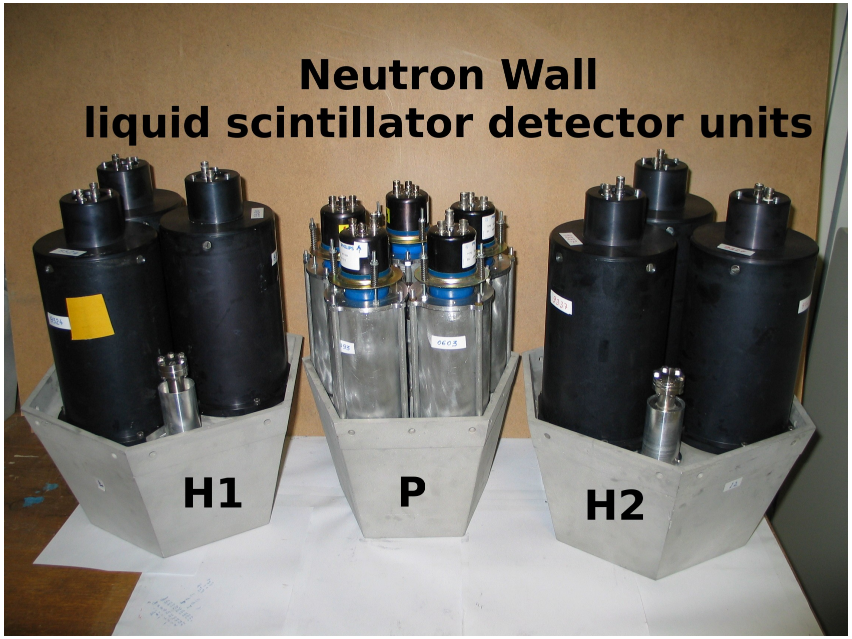
Neutron Wall history

- Built for EUROBALL in 1995-1997
- Persons responsible for the development/construction:
  - Detectors and design: H. Grawe (GSI), Ö. Skeppstedt (Chalmers), M. Moszynski (Swierk)
  - Electronics: D. Wolski and M. Moszynski (Swierk)
- Financed by: Sweden, UK, Germany, Poland
- Experiments performed at EUROBALL/LNL, EUROBALL/IReS, EXOGAM/GANIL
- Owned by the European Gamma-Ray Spectroscopy Pool (former EUROBALL equipment)
- Located at GANIL (since 2005)

Neutron Wall detectors



- Liquid scintillator = BC501A
- Hexagonal detectors (H1,H2):
  - H1: 10 units
  - H2: 5 units
  - 3 segments/unit
  - 3.2 litres/segment
  - 1 PMT/segment: XP4512PA
- Pentagonal detector (P):
  - 1 unit
  - 5 segments/unit
  - 1.1 litre/segment
  - 1 PMT/segment: XP4312B
- Detector "thickness" = 15 cm

Neutron Wall array

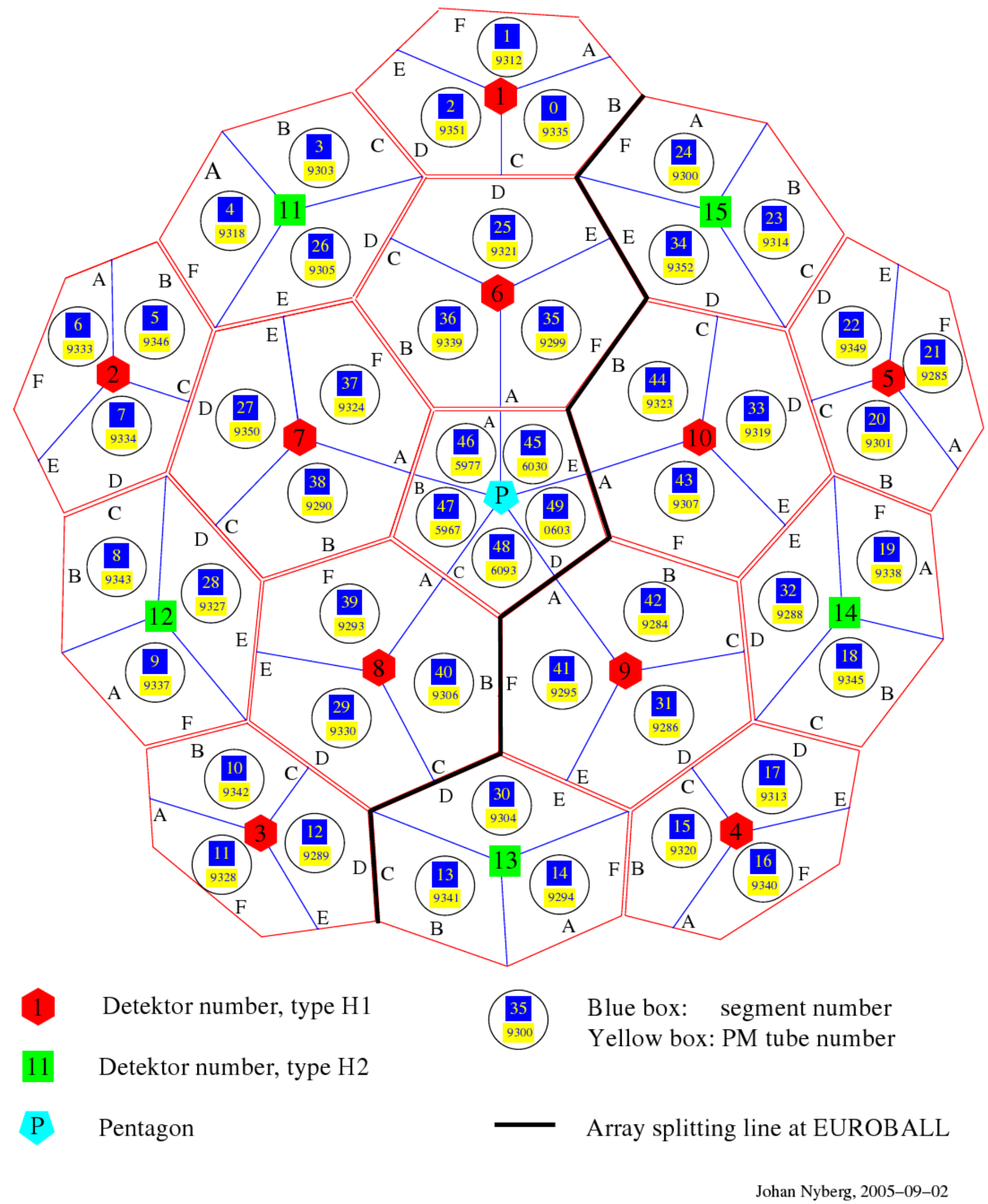
- Total number of detector segments: 50
- Total liquid scintillator (BC501A) volume: 150 litres
- Total solid angle coverage: ≈ 1 π (Ω/π = 0.5% per hex.)
- Mounted at 0° (forward hemisphere)
- Distance target to front face of detector: 51 cm

- Position of neutron detectors in array: http://nsg.tsl.uu.se/nwall/geometry/angles.html

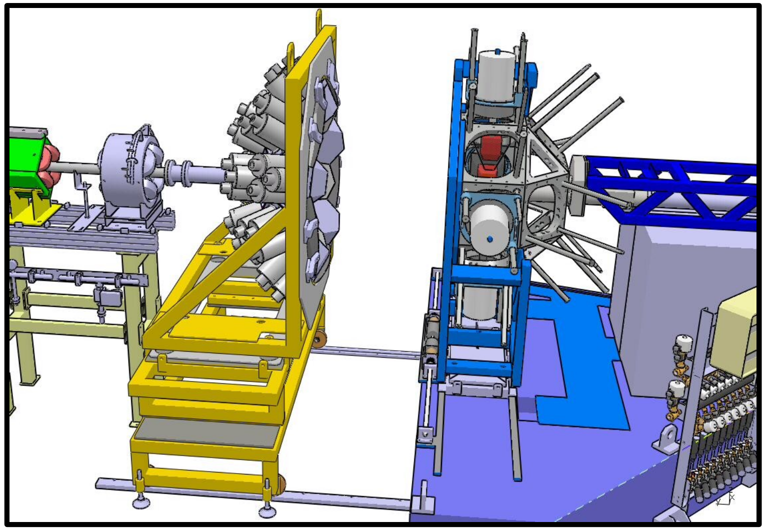
Detector and PMT numbering

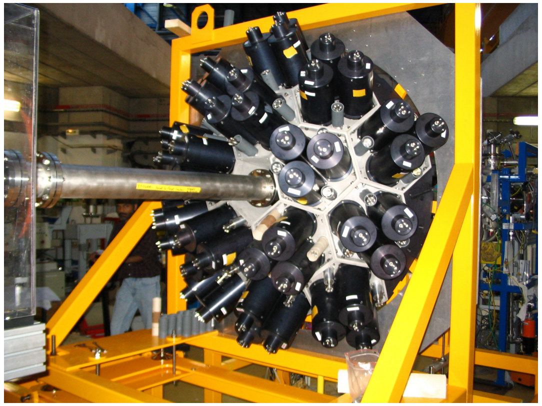
NEUTRON WALL

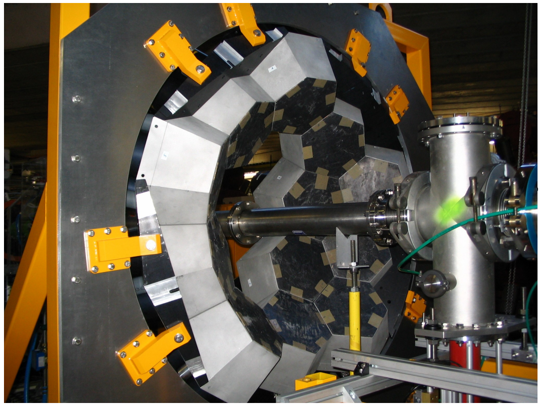
viewed from outside of the array downstream of the target position



Neutron Wall frame







Neutron Wall at the G2 beam line at GANIL

- New holding structure (frame) with rails designed and built by GANIL in 2004
- Has been used in EXOGAM experiments at the G2 beam line, GANIL, 2005-2006
- Present setup requires a beam dump after/outside the Neutron Wall ⇒ usage of 0° pentagon not possible

Frame will fit at beam line G1 together with EXOGAM and VAMOS (not tested yet)

Front-end Electronics

- NIM based
- Neutron-gamma PSA:
  - 2 channel NIM unit, NDE202
  - Zero-Cross-Over (ZCO) PSA method
  - Built by D. Wolski et al., Swierk

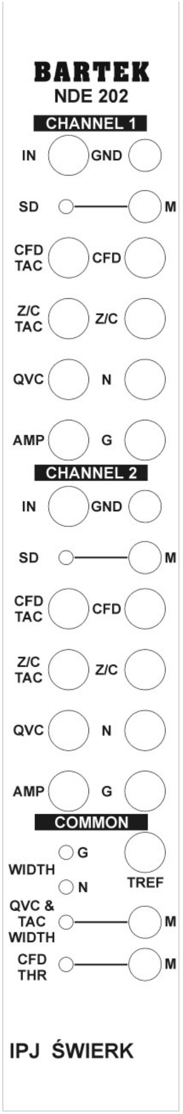


Fig. 3 Front panel of NDE 202 module

NDE202 block diagram

- CFD for leading edge timing
- Bipolar shaping amplifier for ZCO timing
- Input signals:
  - anode signal
  - external time reference (TREF)
- Output signals (many):
  - ZCO TAC:
    - start ZCO
    - stop CFD or TREF
  - TOF TAC:
    - start CFD
    - stop TREF
  - QVC:
    - integr. Q of anode signal
  - N,G:
    - current (1 mA) "sumbus" signal for trigger system

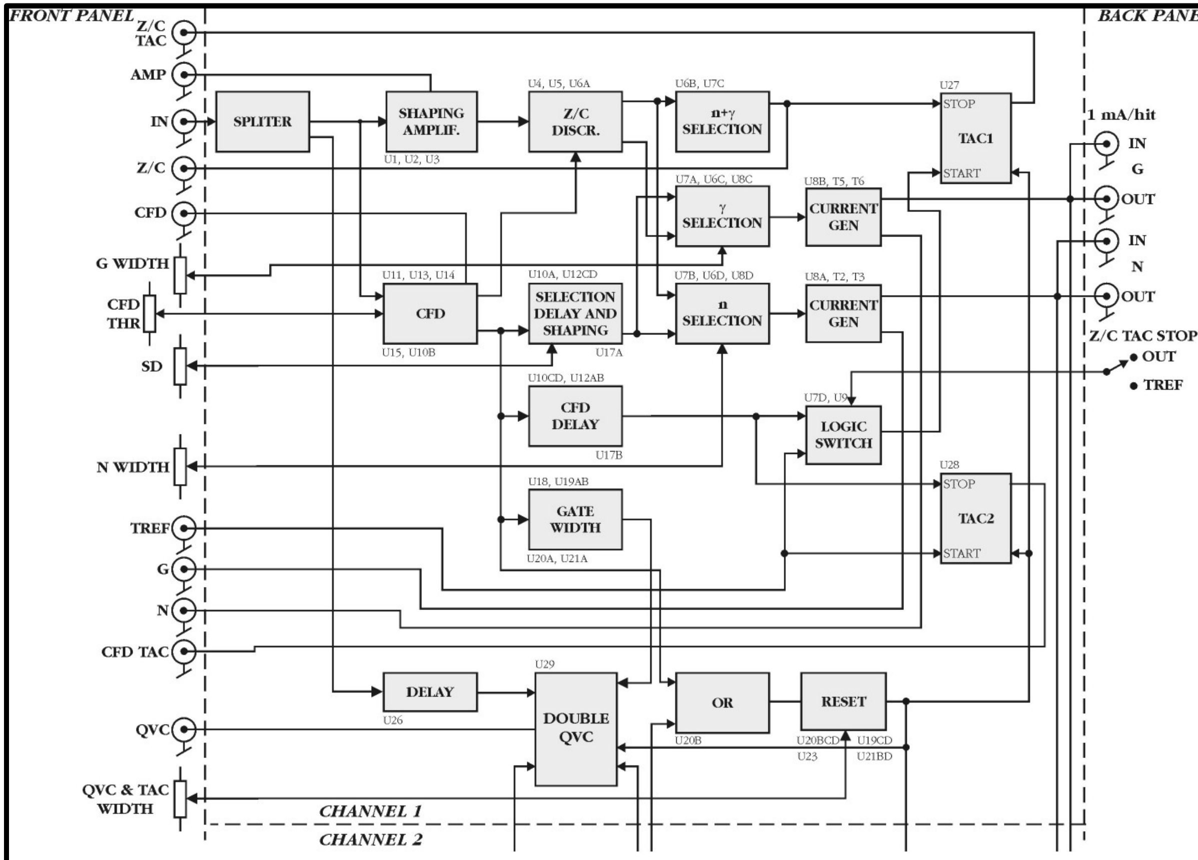


Fig. 1 Block scheme of one channel

Trigger, ADCs

- Trigger signal:
  - based on neutron fold signal: detection of at least N neutrons, N≥1
  - a similar gamma fold signal is also avialable
  - available about 450 ns after the output of the NDE202 CFD output
- ZCO TAC, TOF TAC, and QVC signals:
  - digitized by 32 ch / 14 bit peak sensing ADCs located in one of the EXOGAM VXI crates
  - read out though the standard EXOGAM DAQ system

Neutron-gamma discrimination

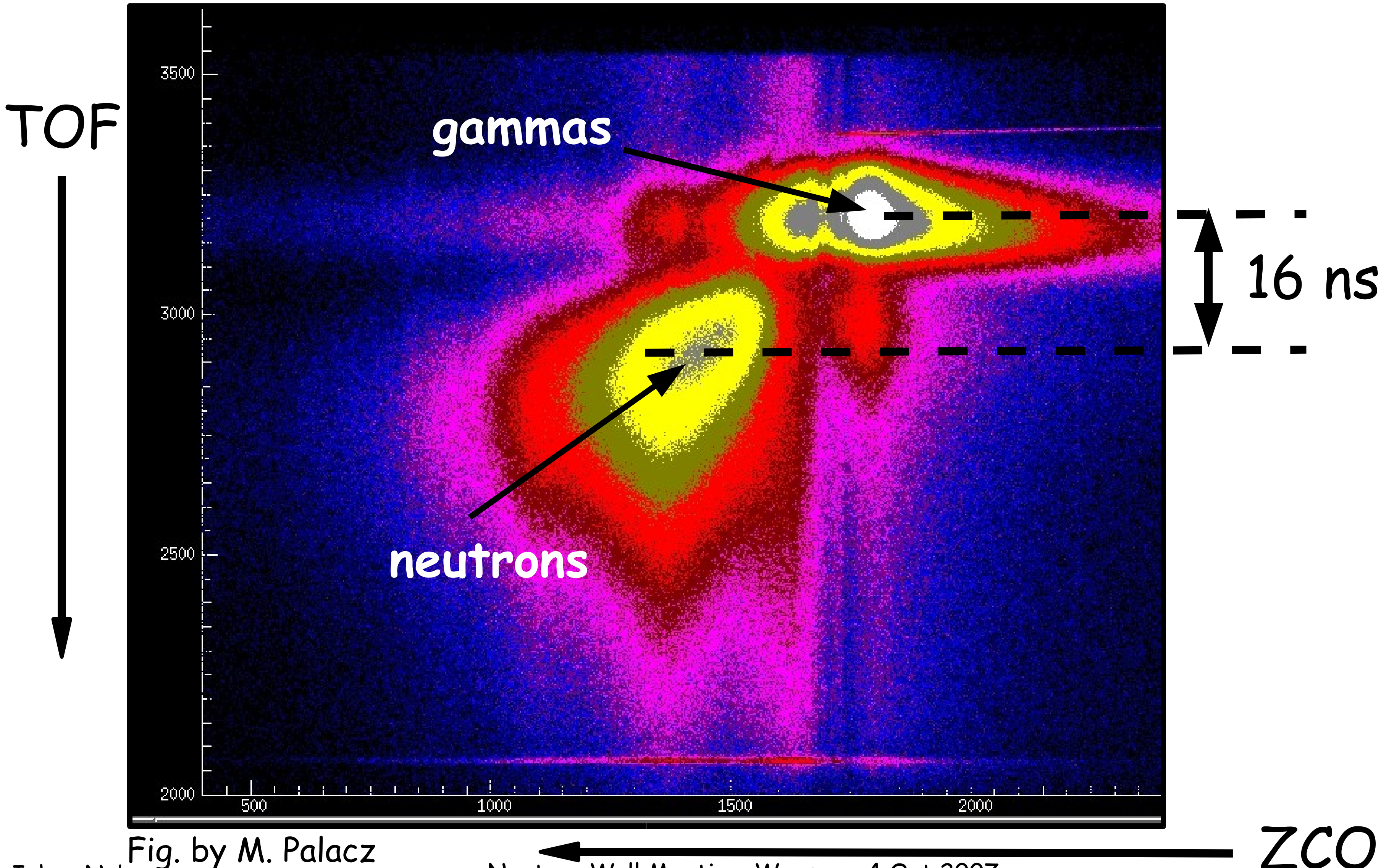
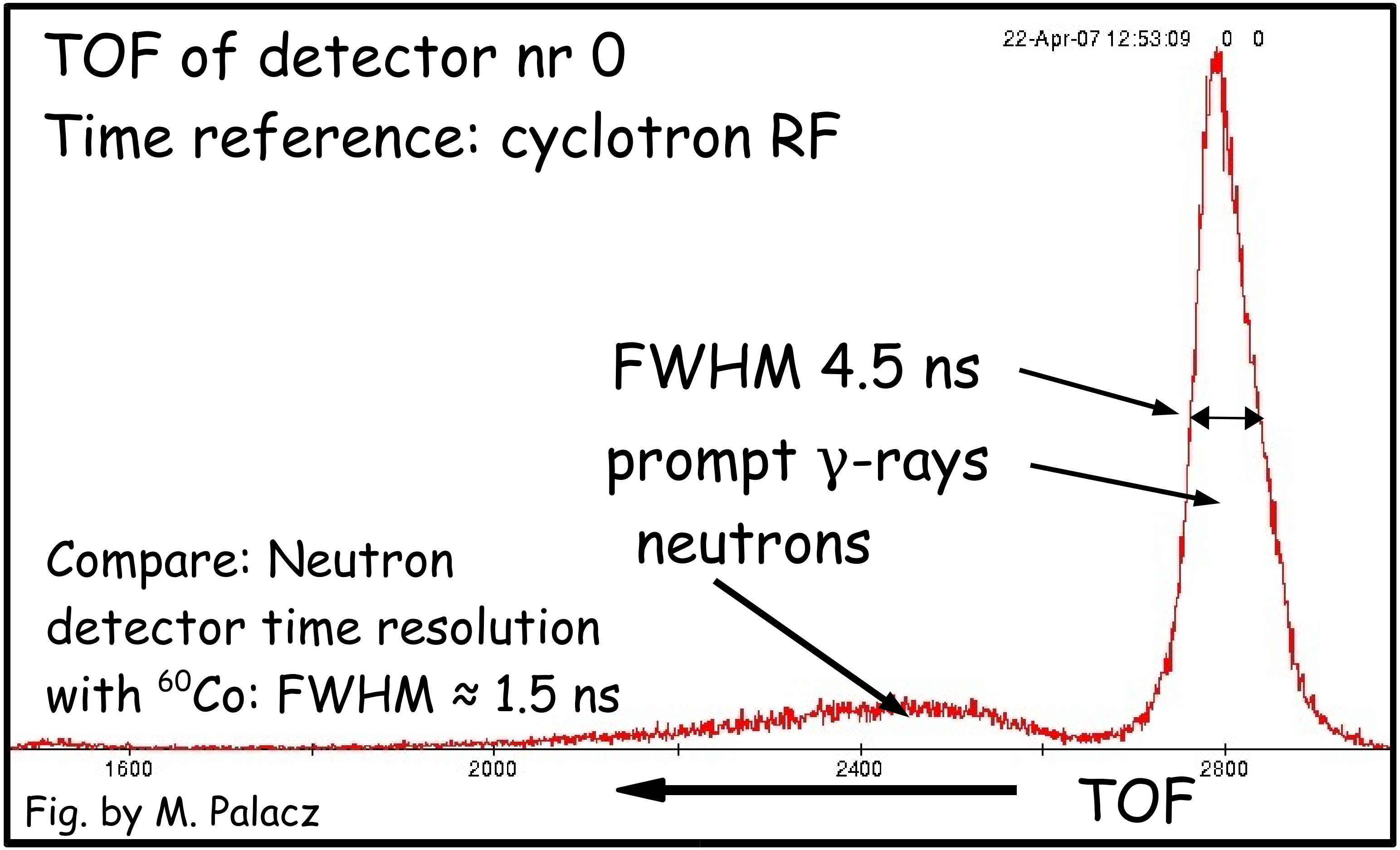


Fig. by M. Palacz

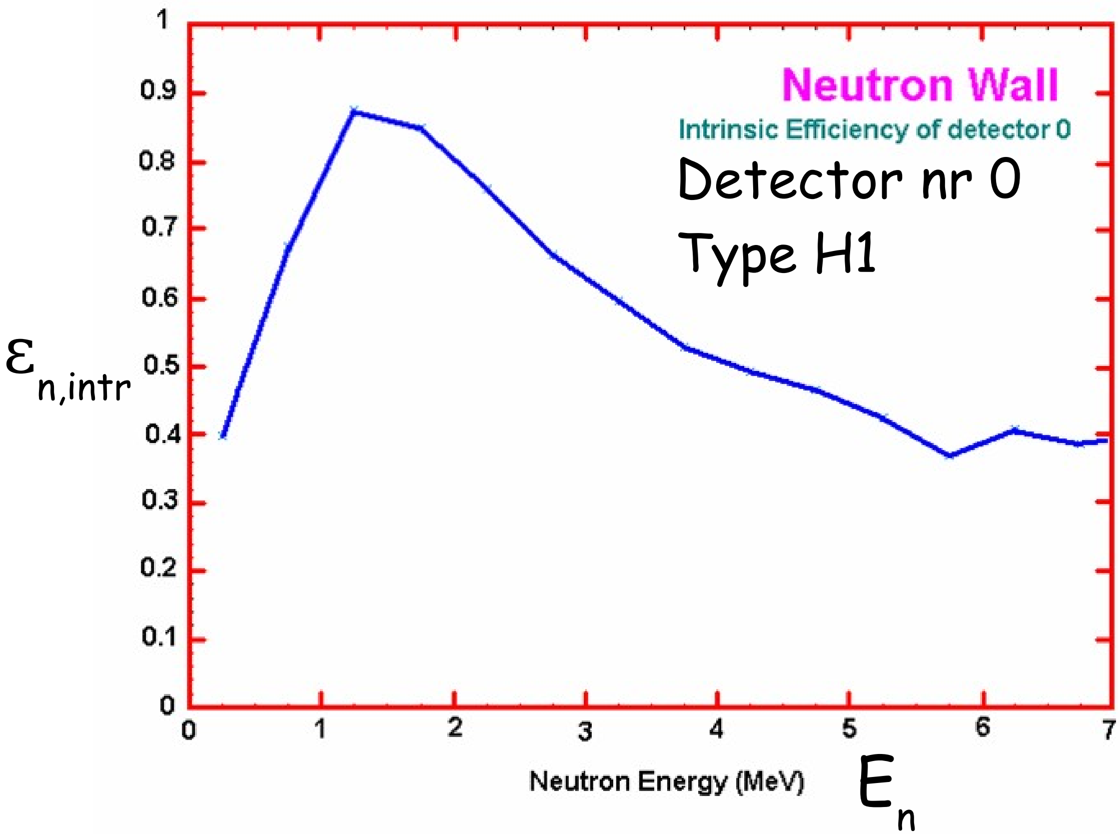
Time resolution and time reference

EXOGAM experiment ^{58}Ni (240 MeV) + ^{54}Fe



Good time reference signal is crucial!

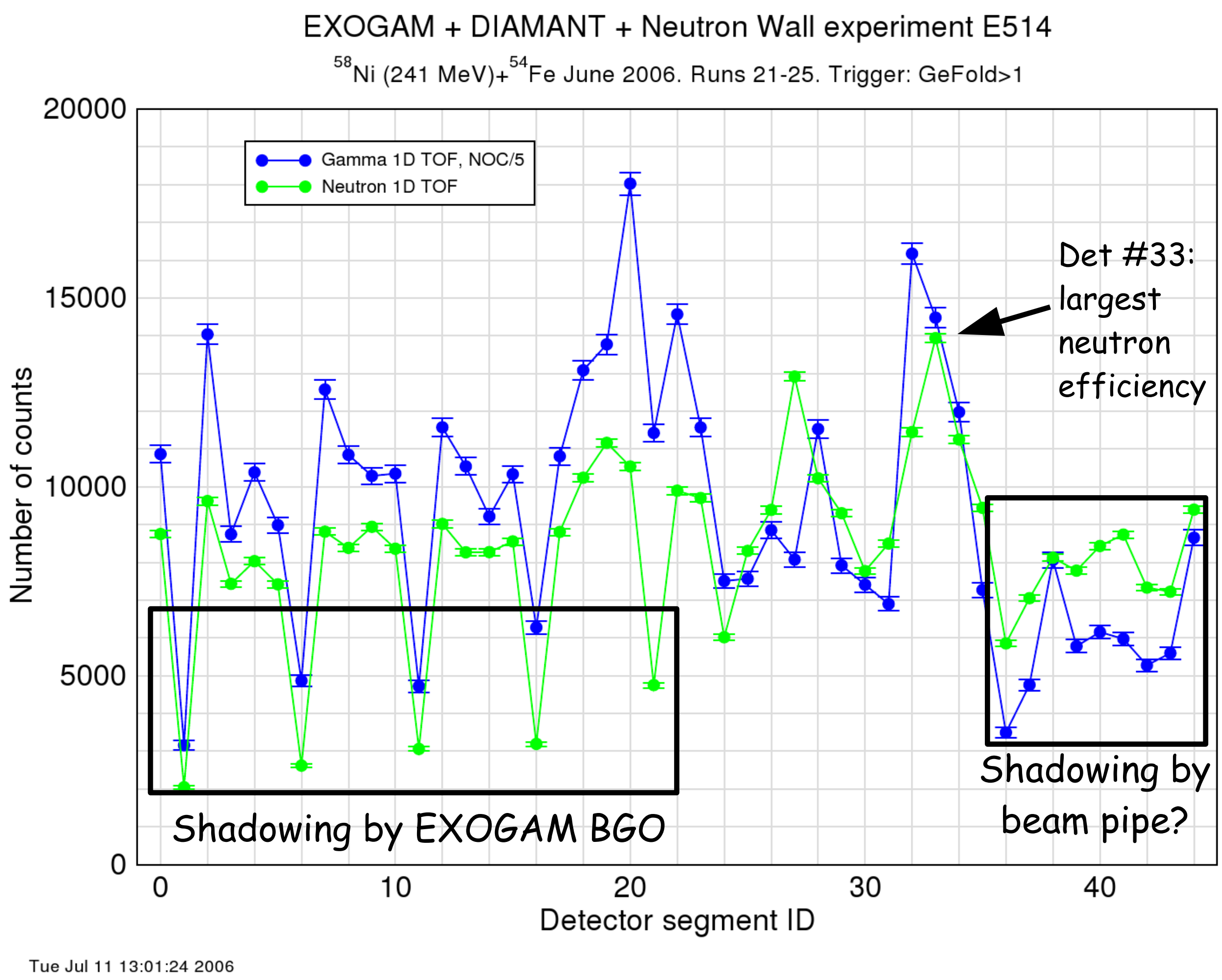
Intrinsic neutron efficiency



- ^{252}Cf source
- BaF_2 detector as time reference
- Neutron energy determined from TOF
- At E_n = 1.3 MeV
  - absolut efficiency for one detector at 51 cm: $\varepsilon_{n,abs} \approx 0.005$

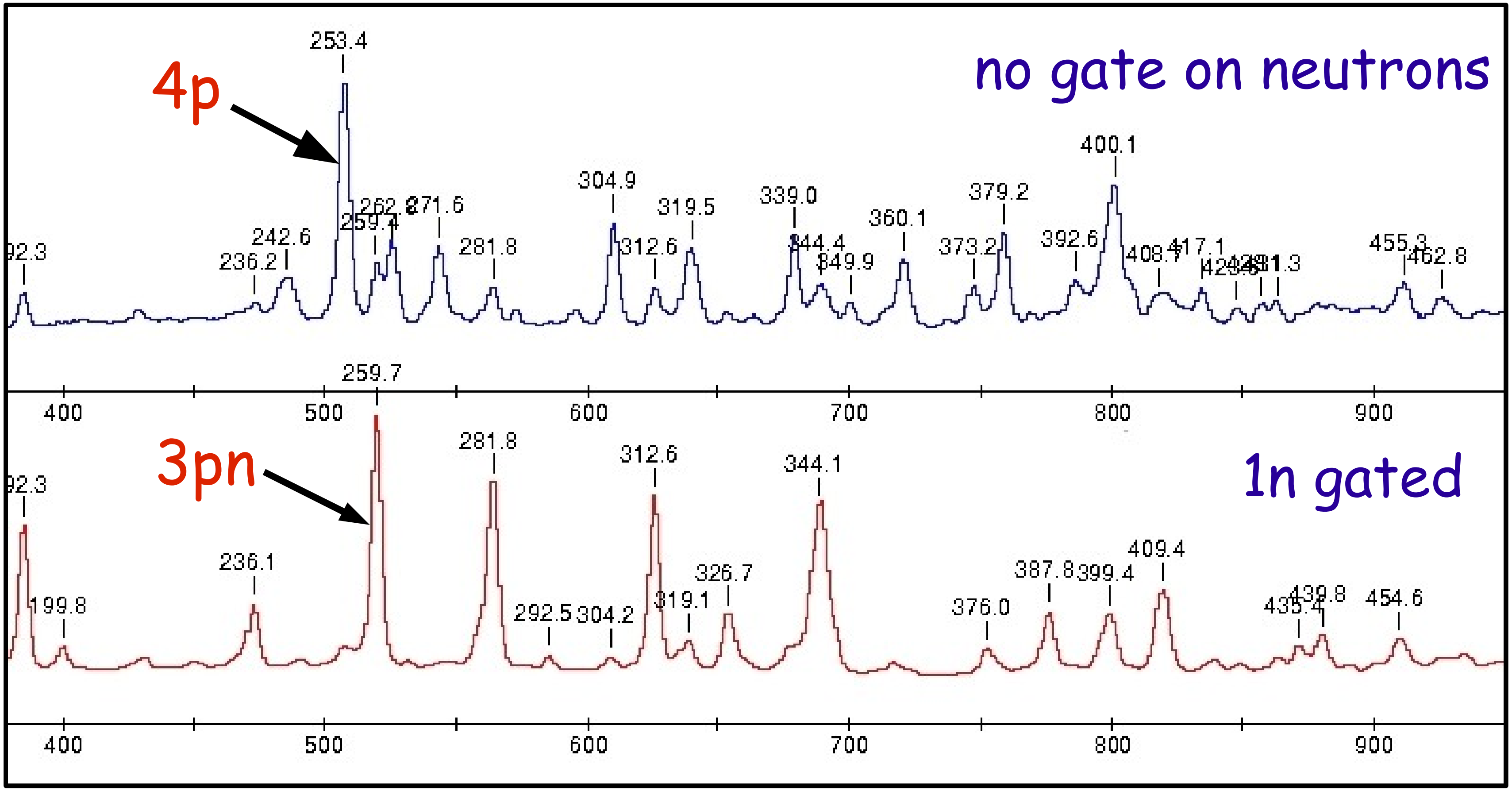
Measurement by A. Chatterjee, BARC, India

Relative efficiency



Efficiency in fusion-evaporation reaction

EXOGAM experiment: ^{58}Ni (240 MeV) +^{54}Fe



Absolut total 1n efficiency $\varepsilon_{1n} \approx 0.21$

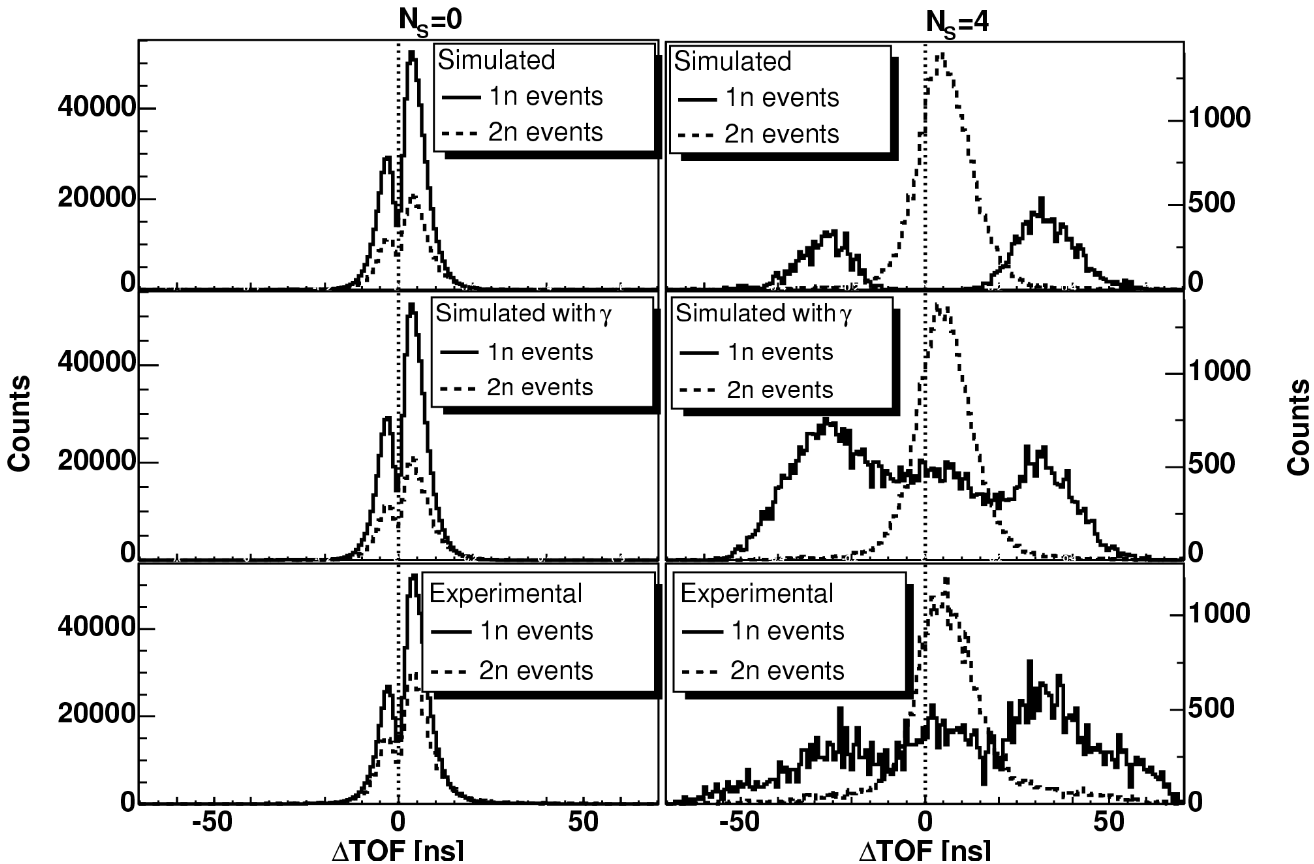
How to increase the neutron detection efficiency

- EXOGAM experiment ^{58}Ni (240 MeV) + ^{54}Fe: $\varepsilon_{1n} \approx 0.21$
- Efficiency can be increased by
  - Including the pentagon: +0.03
  - No shadowing due to EXOGAM BGOs: +0.03
  - All detectors as good as #33: +0.05 (?)
- This would give $\varepsilon_{1n} \approx 0.32$
- Important increase, especially for experiments in which ≥ 2 neutrons must to be detected.

Neutron scattering in the Neutron Wall

- Probability of 1 neutron giving a signal in 2 or more neutron detectors ≈ 7%
- A serious problem in search for weakly populated ≥2n reaction channels: scattered neutrons from much stronger 1n channels are mis-identified as 2n, 3n,... chs.
- Developed and tested methods to detect scattered neutrons:
  - Delta-TOF
  - Neighbour rejection
  - Deposited energy vs TOF
- Small amounts of gamma rays mis-identified as neutrons reduces dramatically the quality of the neutron scattering reduction
- Ref: J. Ljungvall et al., NIM A528(2004)741

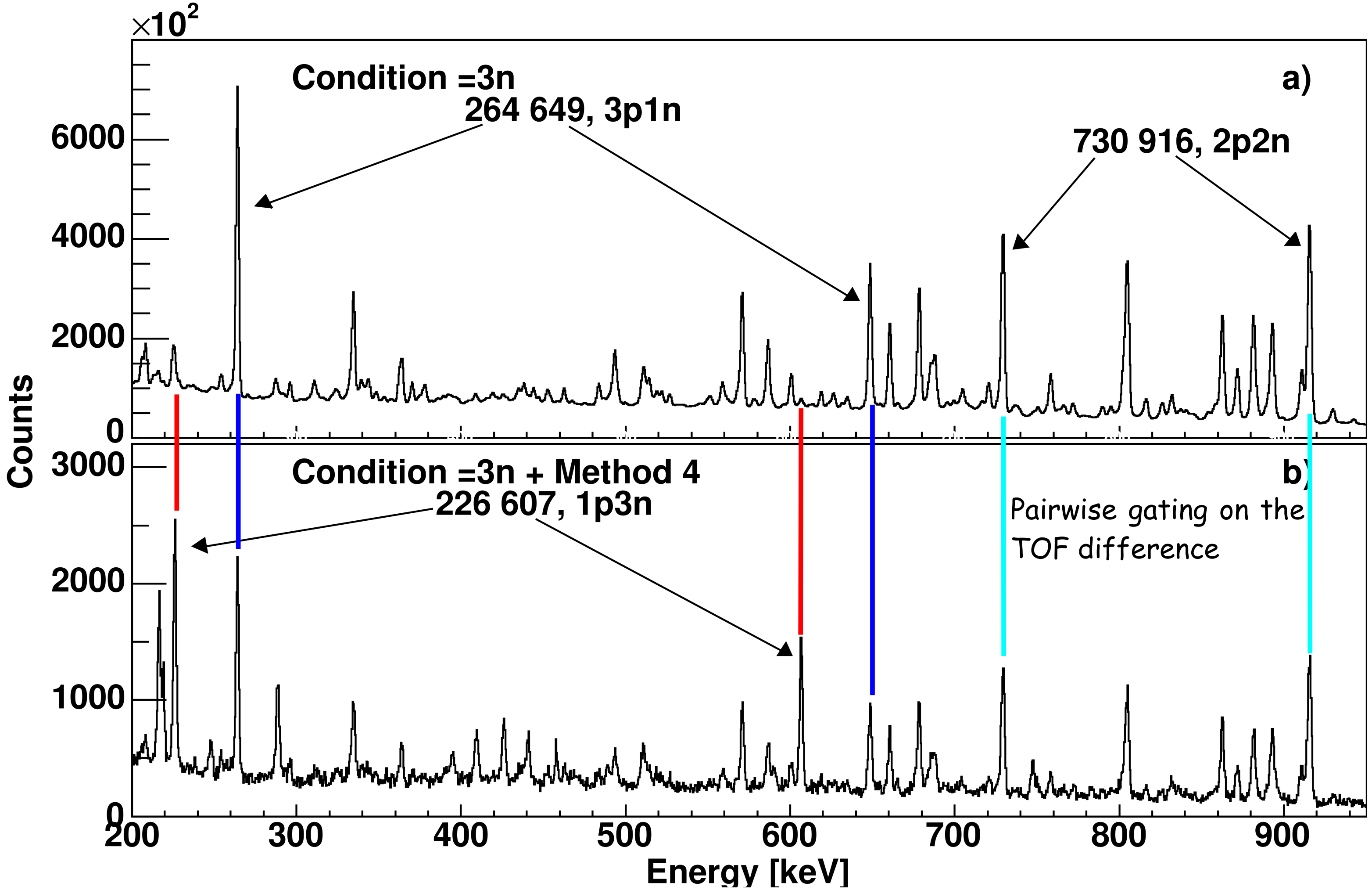
Discrimination of scattered neutrons by using the time-of-flight differences between neutron detector segments



GEANT4 simulation of the Neutron Wall, J. Ljungvall et al., NIM A528(2004)741
Original idea: J. Cederkäll et al., NIM A385(1997)166

Discrimination of scattered neutrons

Data from EUROBALL IV experiment ^{58}Ni(205MeV)+^{45}Sc



J. Ljungvall et al., NIM A528(2004)741

Possible future improvement: digital electronics

- Replace the aging analog NDE202 PSA units with digital electronics.
- FADC with 10 bits & 200 MHz (or more) $\Rightarrow$ neutron-gamma separation which is as good as obtained with the NDE202 (see P-A Söderströms talk tomorrow).
- Such FADC are commercially available.

Some open questions regarding digital electronics

- Would 200 MHz give good enough TOF resolution?
- Is it necessary to implement PSA in real-time or can one read out the waveforms and do PSA offline? Two possible problems if this is done:
  - Event sizes much larger: 10 bits/200 MHz FADC, 500 ns traces $\Rightarrow$ 200 bytes/detector. Can be "compressed"?
  - Not possible to create a fast neutron trigger signal. If needed, at least a simple/rough real-time neutron-gamma PSA should be implemented.
- Can we find PSA algorithms that give better n-g separation than the analog system?
- How to finance the upgrade to digital electronics?

Neutron Wall references

- Web site: http://nsg.tsl.uu.se/nwall/
- ELOG: https://www.agata.org/elog/nwall/
- Technical papers:
  - The EUROBALL Neutron Wall - design and performance tests of neutron detectors, Ö. Skeppstedt et al.
    - NIM A421 (1999) 531-541
  - Monte Carlo simulations of the Neutron Wall detector system, J. Ljungvall et al.
    - NIM A528 (2004) 741-762

The end

- Many slides shown were made by Marcin Palacz. Thanks Marcin!